Development of Multilayer Readout Wiring for Large-format TES X-ray Microcalorimeter Arrays

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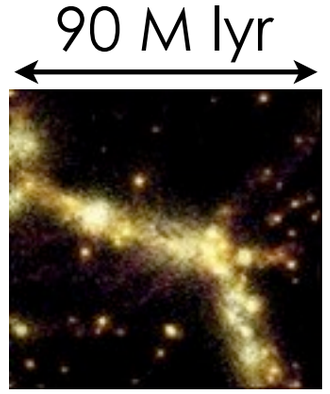
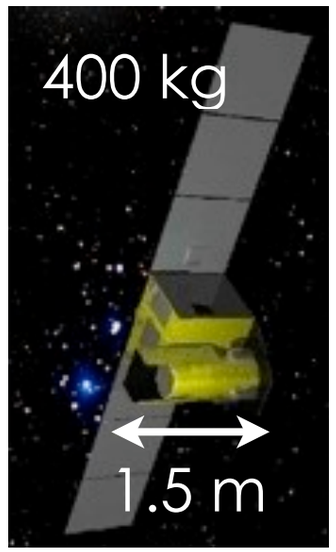
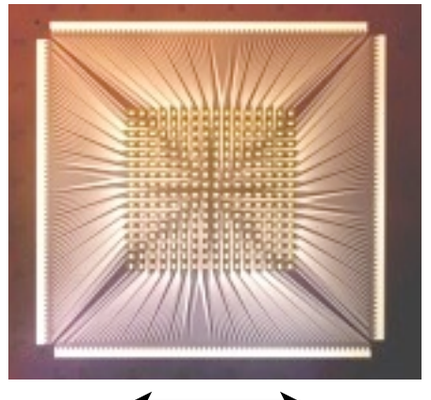
Motivation

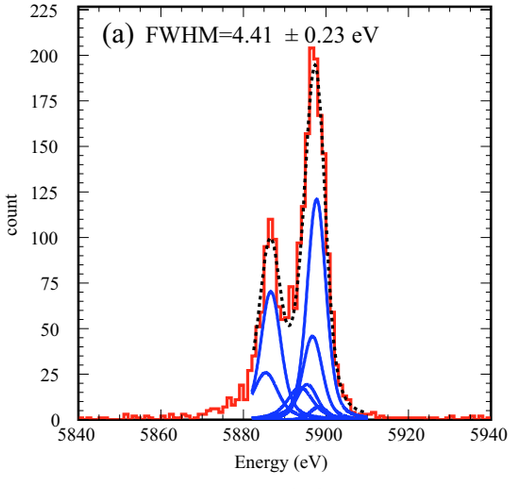
- Next X-ray astronomy satellites
  - kilo~Mega pixel TES array
- DIOS (~2016) (Ohashi+05 SPIE)
  - Mapping of missing baryon
  - ΔE ~ 2 eV, Area ~10x10 mm^2 @ 0.2-1.5 keV
- Good ΔE → Small pix $\Delta E \propto \sqrt{CT^2/\alpha}$
- 16x16 array w/ 200 μm sq TES
  - wiring width **10 μm**
- **DIOS needs >20x20**







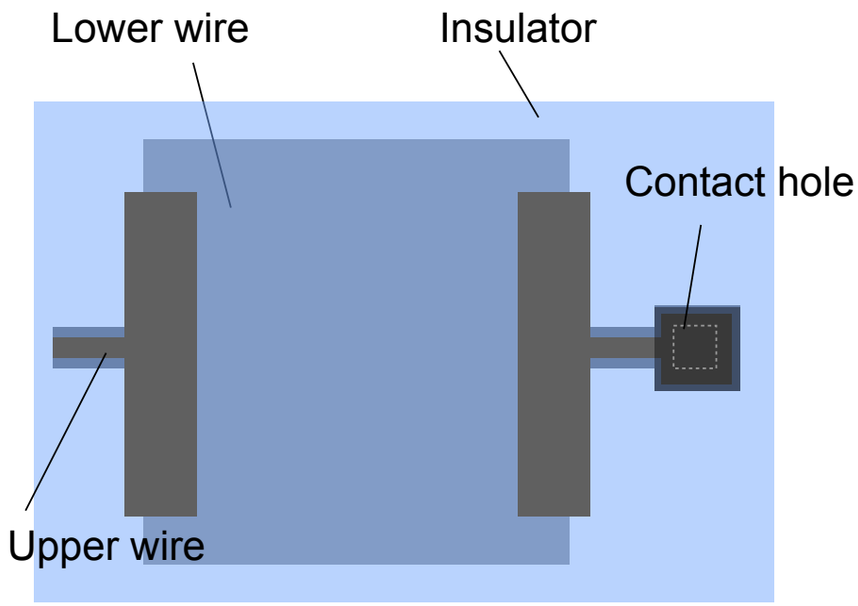
4.4 eV @ 5.9 keV

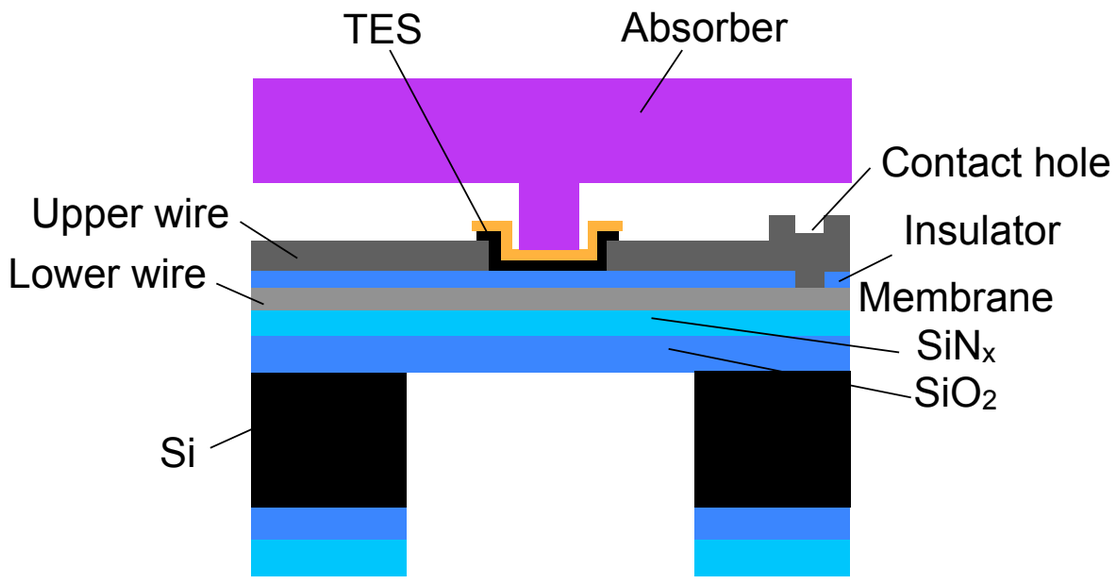


Ezoe+09 LTD

Key technology

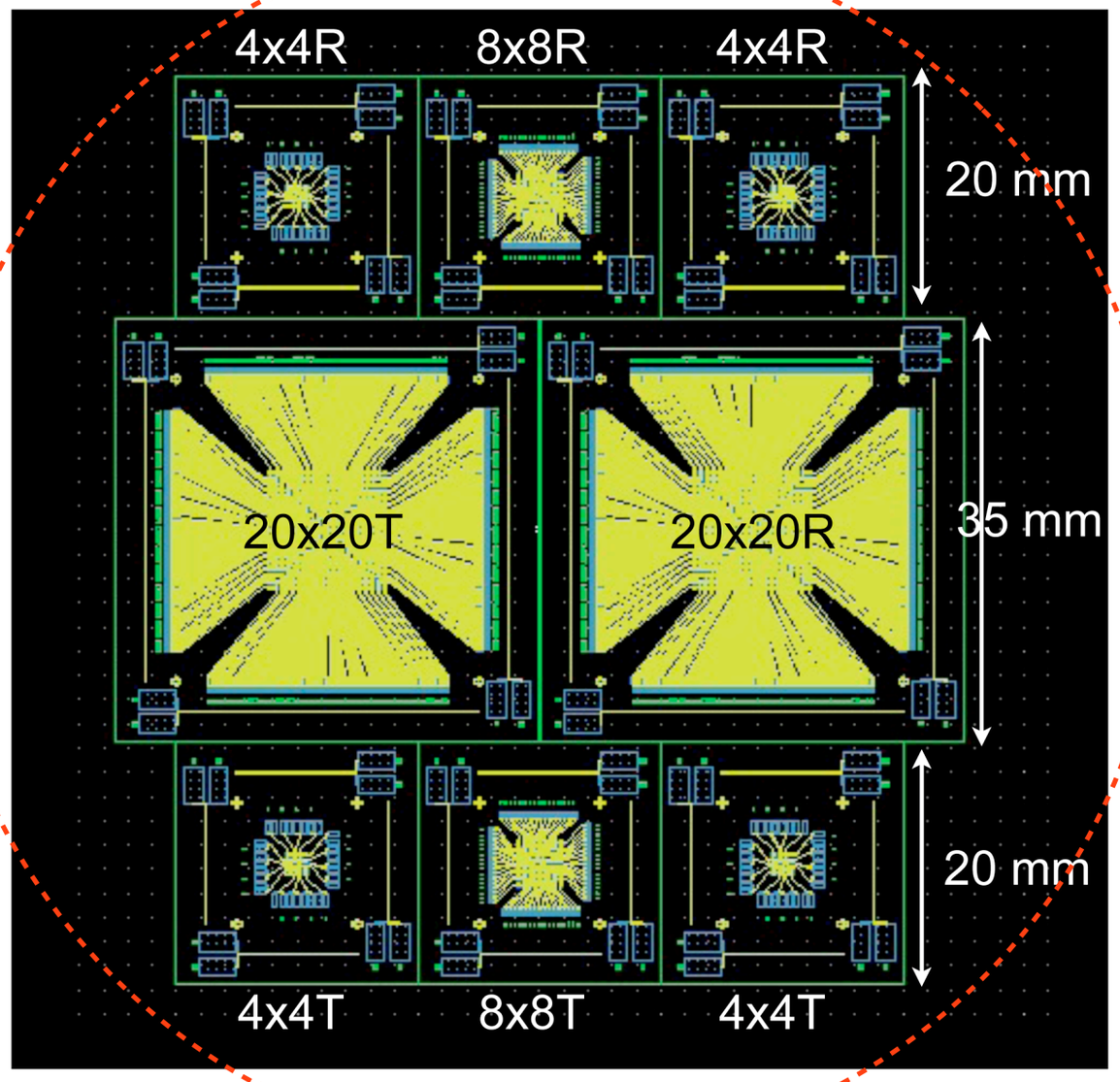
- Superconducting readout wiring
- Key for many missions (IXO, DIOS, Xenia)
- Multilayer readout
  - Space saving
  - Min mutual inductance
- Development plan
  - Wirings w/o TES
  - Wirings w/ TES



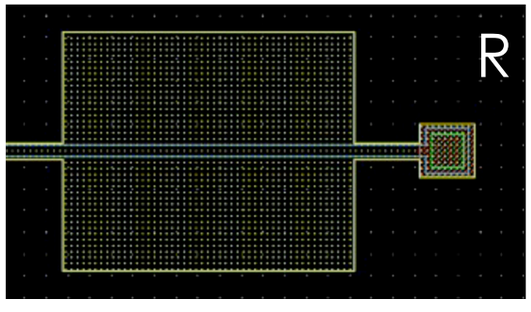


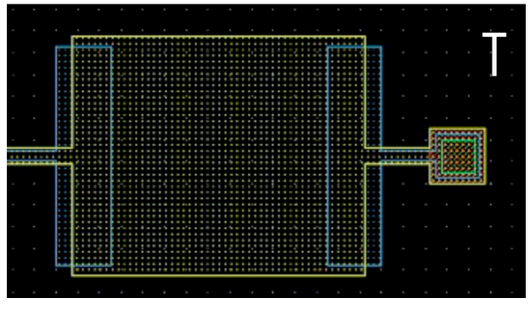
Design

- Four 4x4, two 8x8, two 20x20 wirings in 4 inch Si
- TES size 200 μm sq, pitch 500 μm sq for DIOS (Ezoe+09 LTD)



- width (upper & lower)
  - 4x4, 8x8 20 & 30 μm
  - 20x20 10 &15 μm
- pix type





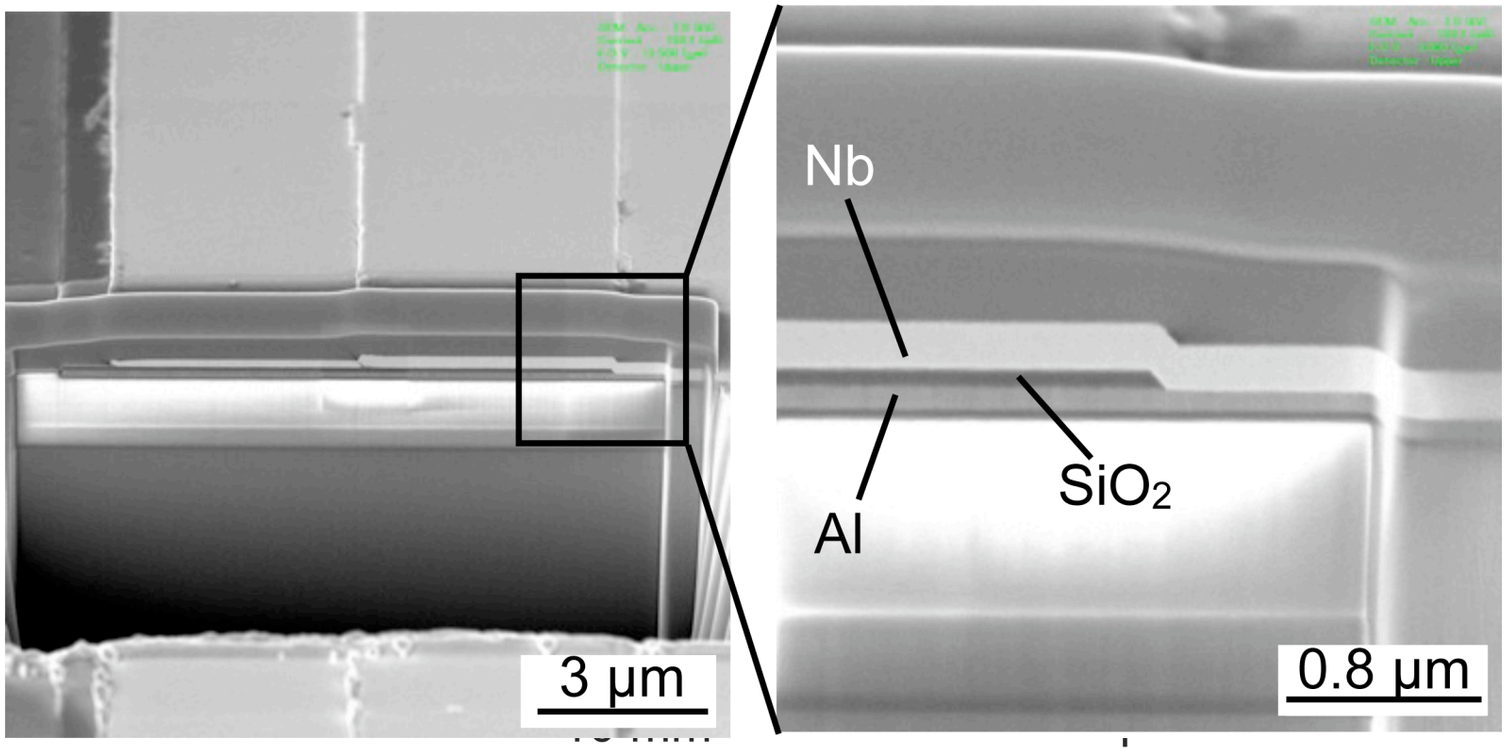
- material

ID	upper wiring	lower wiring
MLR #1	Al t100 nm	Al t100 nm
MLR #2	Al t50 nm	Al t100 nm
MLR #3	Nb t50 nm	Al t100 nm
MLR #4	Nb t100 nm	Al t100 nm

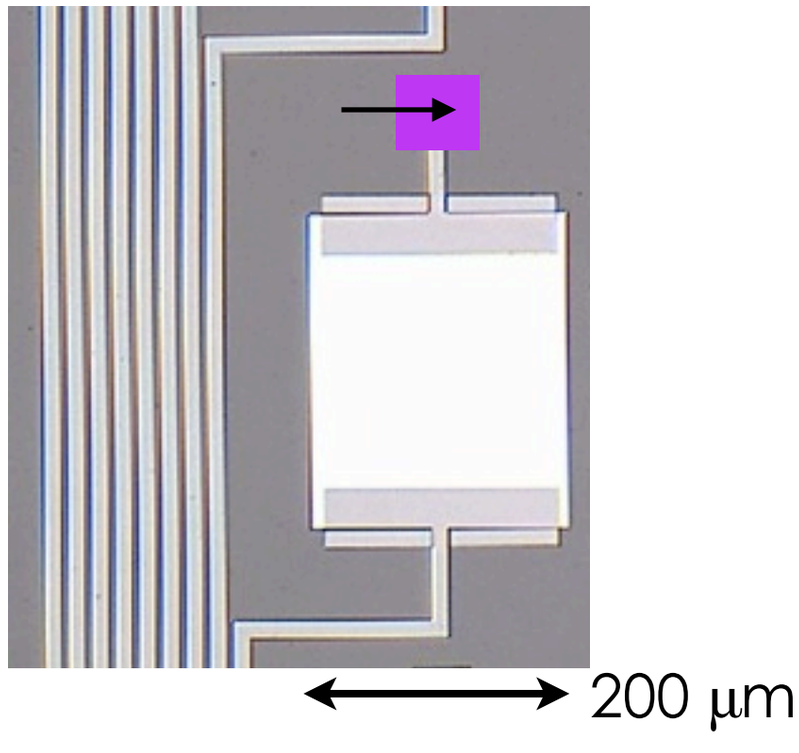
Fabricated wiring samples

- MLR #1, #2 : Al t50 or 100 nm + Al t100 nm
- MLR #3, #4 : Nb t50 or 100 nm + Al t100 nm
  - ☑ High alignment accuracy (≲1 μm)
  - ☑ Good contact by eye check

Contact hole cut by Focused Ion Beam



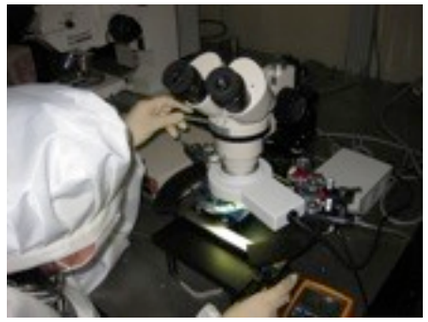
MLR #4 20x20 T



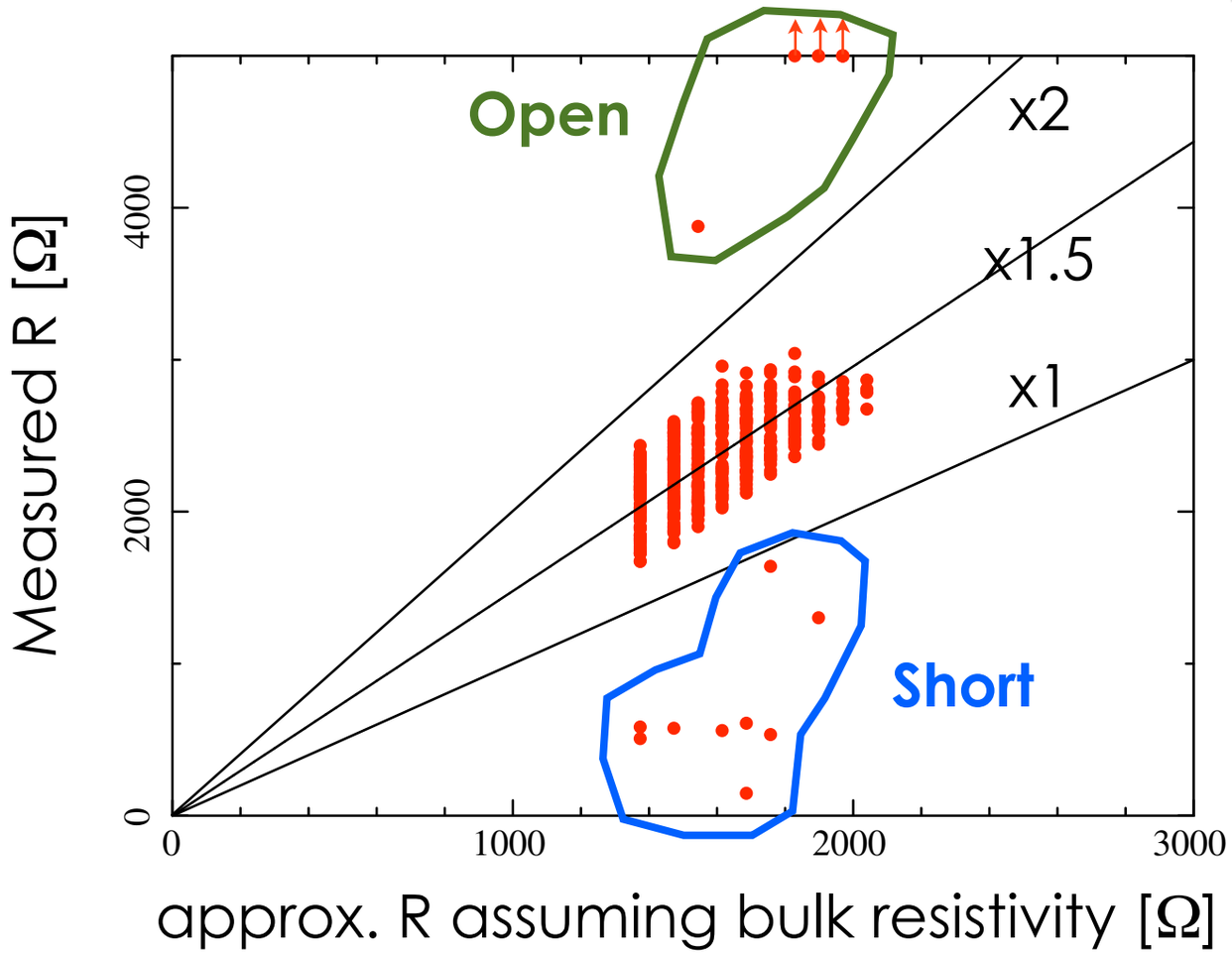
Resistance check at room T

All the 400 pix in each 20x20 R sample

☑ High process yields → 95~97 %



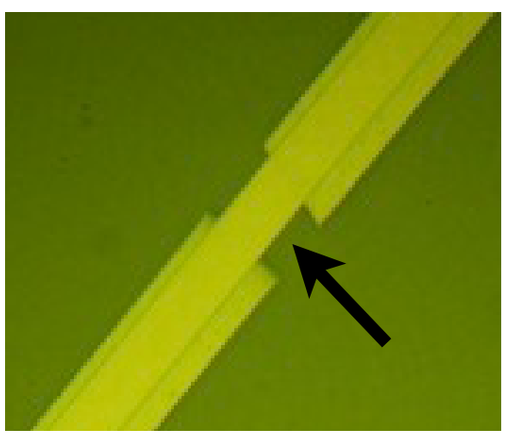
MLR #4 20x20 R (Nb-Al)

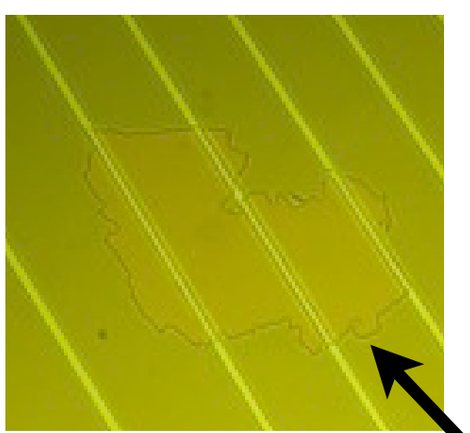


Reason for open/short pix

miss-handling, dust/particle

imperfection of SiO_2

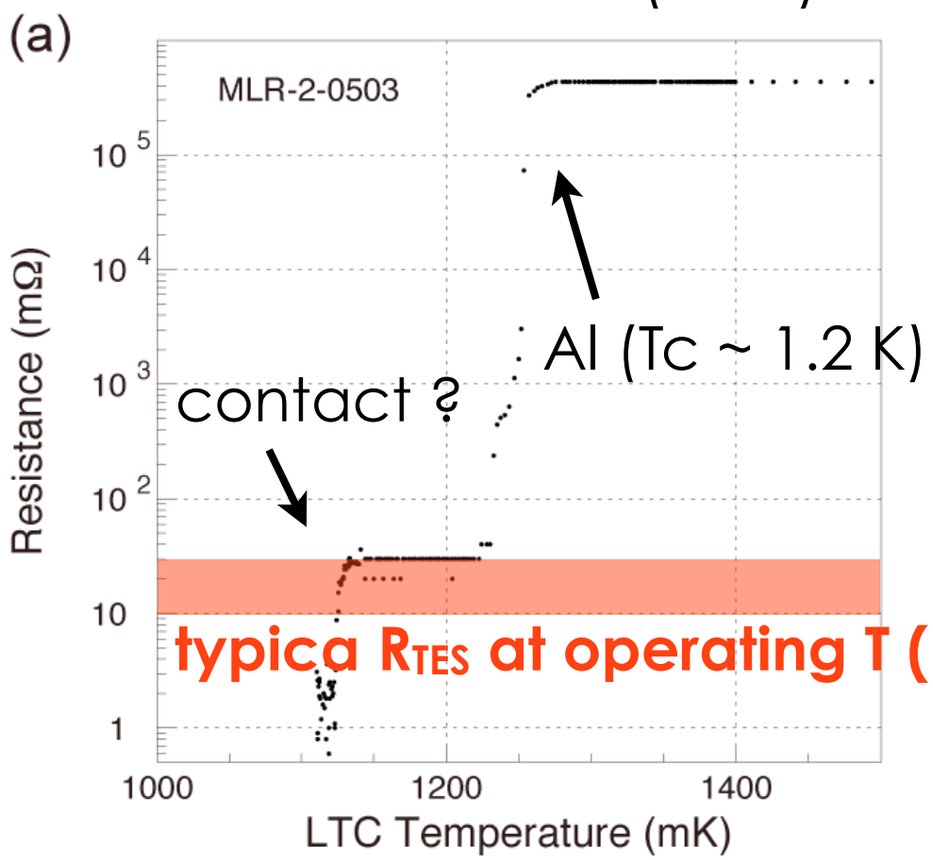




Resistance check at low T

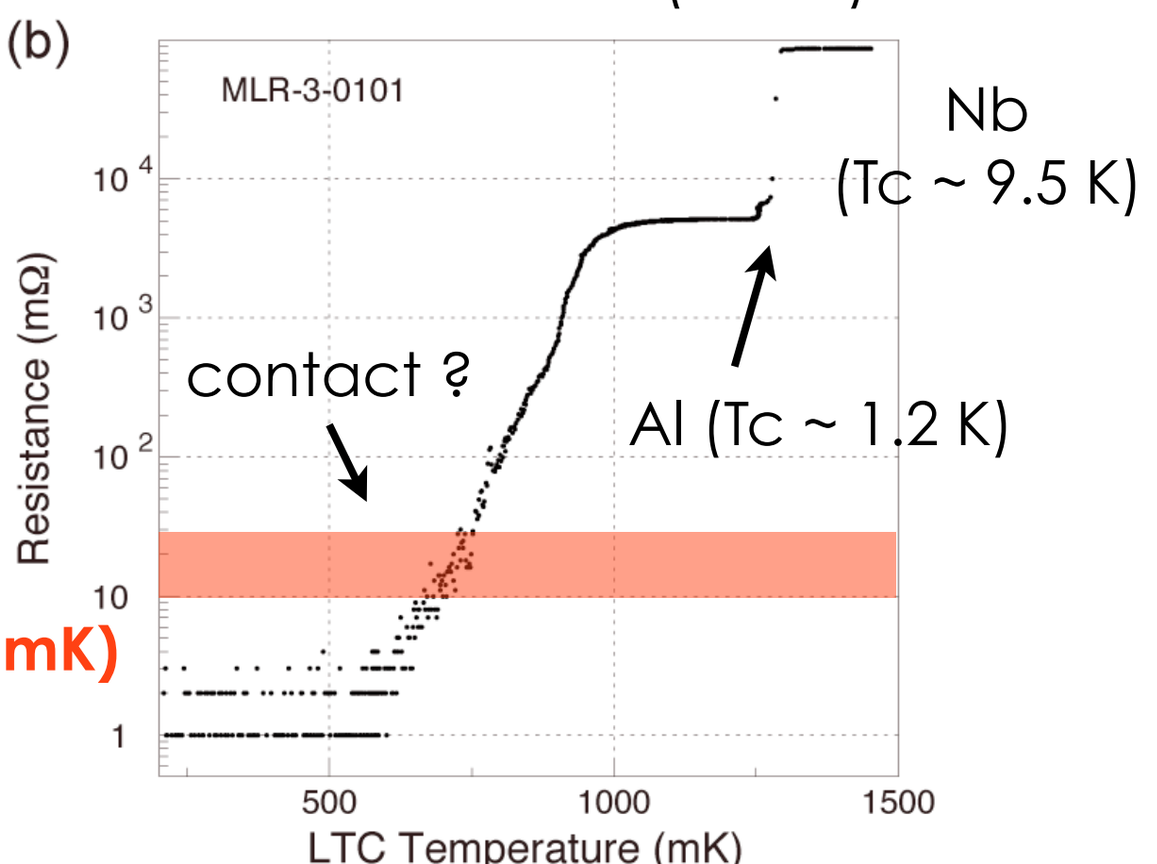
- Transition of 2~4 pix in each 20x20 R sample
- ☑ Al-Al : Sharp transition, Large I_C (>100 μA)
- ☐ Nb-Al : Slow transition, Small I_C (~10 μA)

MLR #2 20x20 R (Al-Al)



~2 mΩ @ 100 mK, 1~100 μA

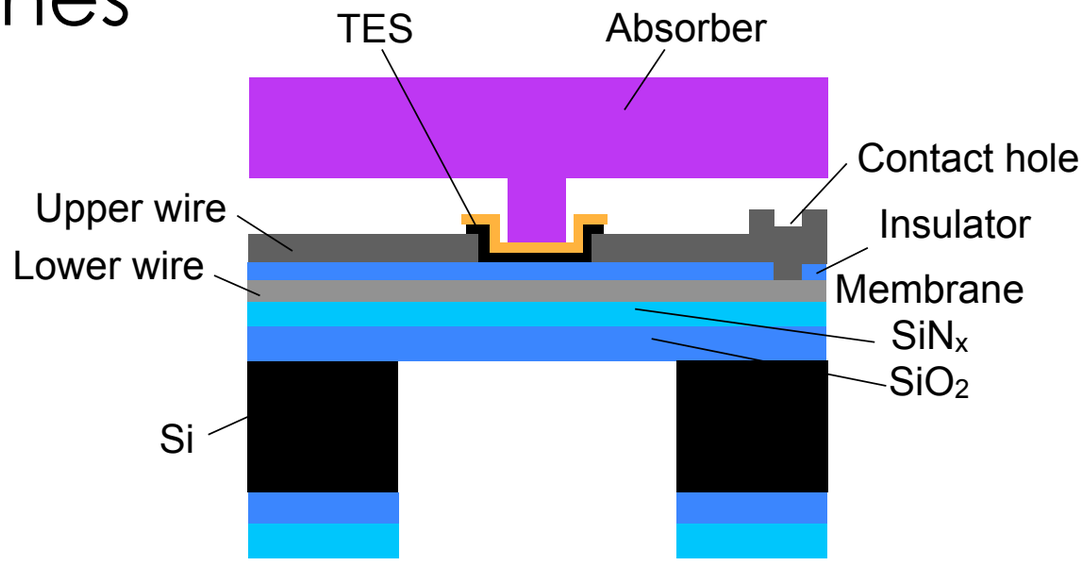
MLR #3 20x20 R (Nb-Al)



~10-20 Ω @ 100 mK, 10~100 μA

Current Status

- We have began to fabricate TES array
  - Al-Al samples are used (MLR #1, 2)
- Conditionings are ongoing
  - TES film upon multilayer wirings
  - Absorber on TES
  - Dry etching for membranes
- Will check RT, ΔE, I_c, noise, electrical cross talks b/w pixels



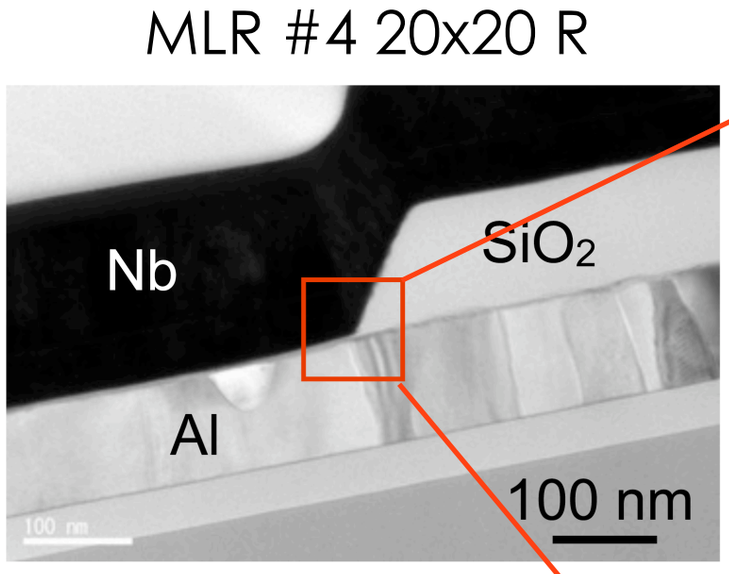
Summary

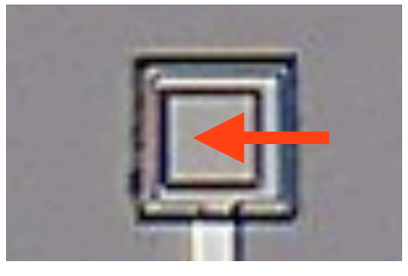
- We have designed and tested a novel readout wiring for a large format array of TES X-ray microcalorimeters.
- It minimizes wiring space and mutual inductance b/w hot and return lines.
- 20x20 wiring samples made of Nb/Al-Al have been successfully fabricated.
  - From R check, high 95~97 % process yield at room T is confirmed.
  - Al-Al wirings show sharp transition and large I_C, while Nb-Al do not. Impurity such as Ar or O may influence the latter.

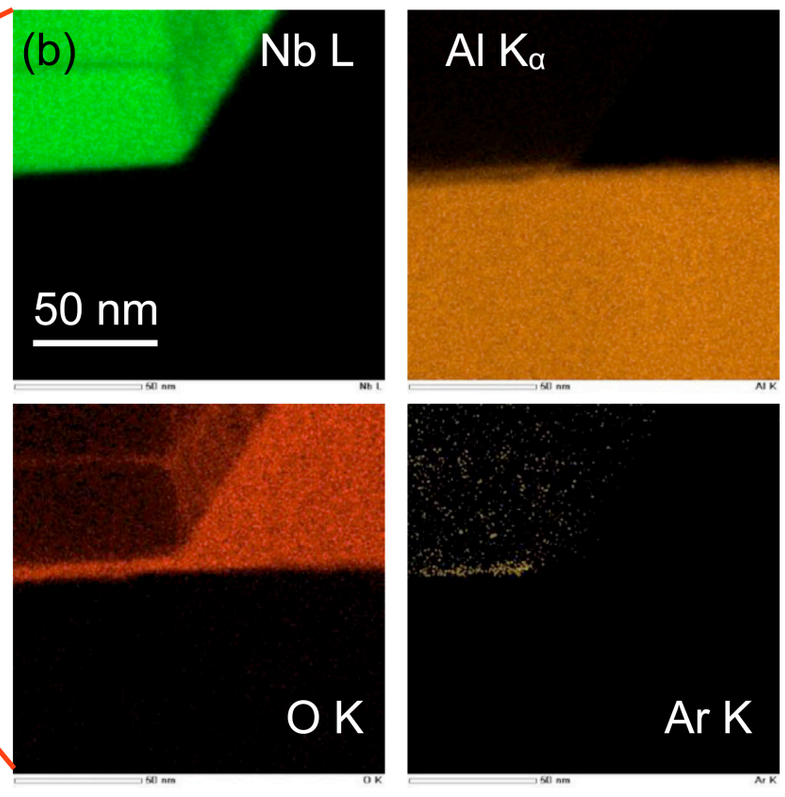
Backup Slides

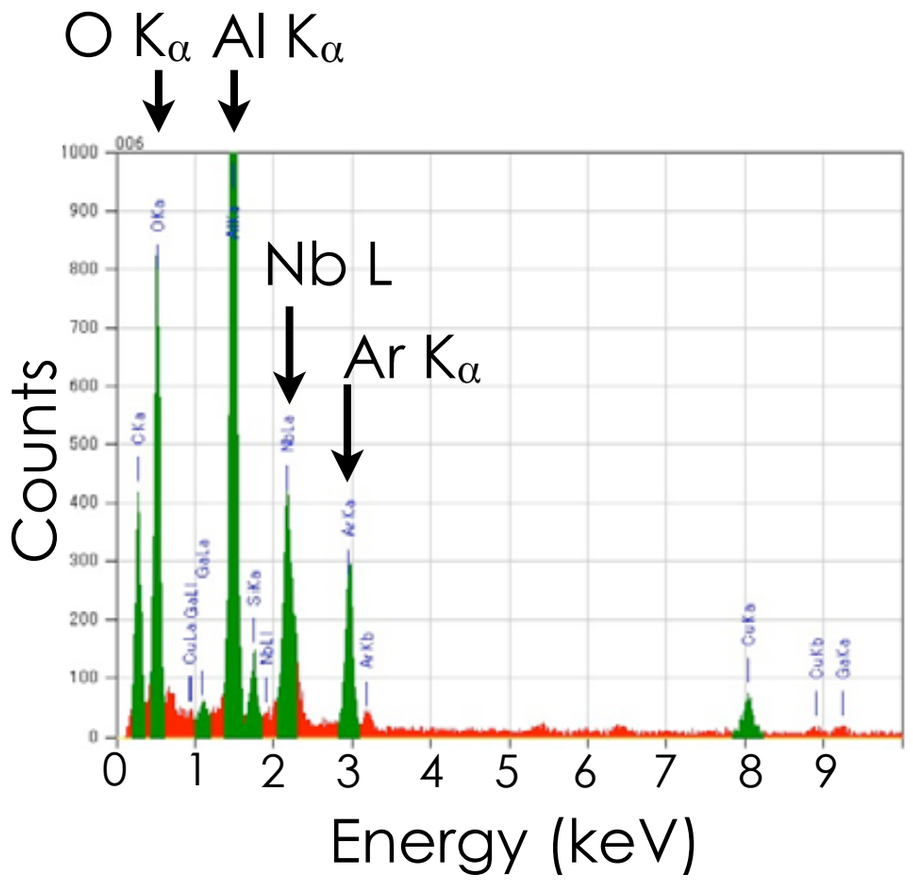
Contact between Nb & Al

- Check chemical composition of contact hole
- FIB → EDS (Energy Dispersive Spectroscopy)









- Impurities (Ar and O) influence the transition ?